Watershed Management in the Paddle River Headwaters

Alberta
FOREST SERVICE

WATERSHED MANAGEMENT IN THE PADDLE RIVER HEADWATERS

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PREFACE

Two events prompted the writing of this report. These are:

1. The completion of the Paddle River flood control dam in August 1985.
2. The expected increase in logging activity in the Paddle River headwaters beginning in the winter of 1985/86.

These events raised two important questions:

1. Is watershed management for flood control still needed now that the dam is completed?
2. Will timber harvesting aggravate flooding?

This report attempts to answer these questions by providing an explanation of the hydrologic principles behind land management for flood control. The explanation is lengthy because the impact of land use on the hydrology of an area is not often understood and cause and effect are not always clear.

The history of the Paddle River flood control program is described in detail. The material is from other reports, but is included to provide an overview of the program for those unfamiliar with it.

The report explains the land management guidelines for the various kinds of activities expected in the headwaters. This section of the report combines into one source the guidelines that have been developed since 1978.

1. INTRODUCTION

For centuries the Paddle River has overflowed its banks. This natural phenomenon did not become a problem until settlement of the flood plain began early this century. Since then, much of the basin has been settled which further increased the economic losses and other hardships associated with flooding.

During the 1970s, the government of Alberta carried out a comprehensive assessment of possible flood control measures which would provide a useful level of flood control using structural and land management measures. Most of the recommended structural control measures, in particular the flood control dam, were completed by the fall of 1985.

In 1978 the government made several recommendations for flood management using watershed (land) management practices. Since 1978, the Alberta Forest Service (AFS) and other government agencies have been involved with the implementation of these recommendations and, when needed, the development and implementation of land management guidelines based on the intent of the recommendations.

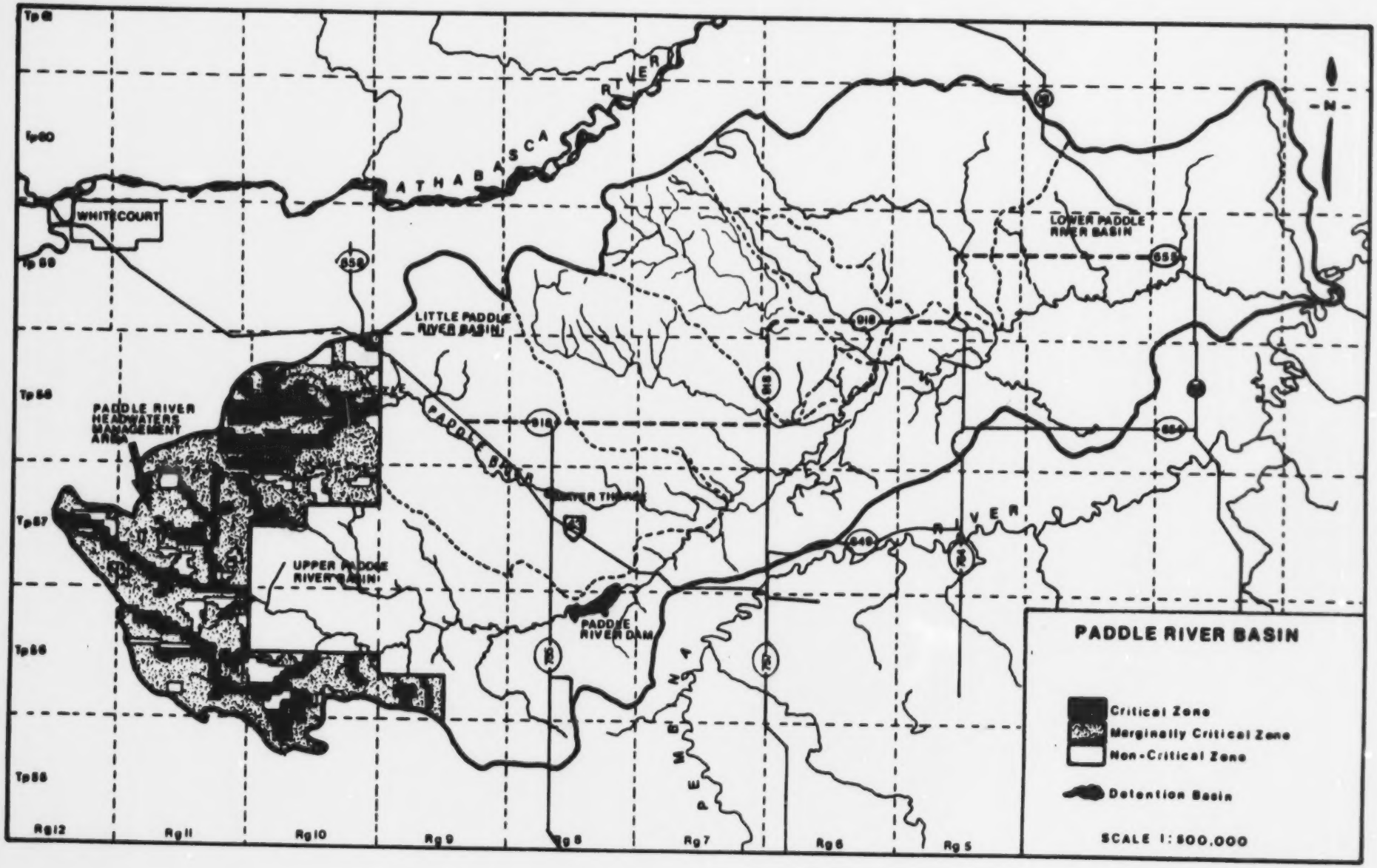
This report is an update of the headwaters watershed management portion of the Paddle River flood control program (Map 1). The objectives of the report are:

1. To provide an overview of the history of the flood control program.

2. To identify the watershed management recommendations and guidelines in effect for the Paddle River headwaters.

3. To explain the hydrologic principles behind the recommendations and guidelines.

Map 1- PADDLE RIVER BASIN



2. HISTORY OF FLOOD CONTROL IN THE PADDLE RIVER BASIN

The following background information is from the Paddle River Basin Land Use and Water Management Committee Report (1978).

"The Paddle River Basin has experienced floods since the turn of the century when settlement of the Basin began. As early as 1912 local farmers petitioned the Provincial Government for assistance. In the 1920's farmers in the upper Basin near Rochfort Bridge unsuccessfully attempted to control flooding. In 1943, the Provincial Government responded to the requests and examined, but did not implement, channel straightening and cut-offs. A reconnaissance study of reservoir sites was also made. In the 1950's, in conjunction with studies of the Pembina River, the Counties of Barrhead and Lac Ste. Anne were offered assistance with respect to channelization which apparently was declined for economic reasons. During 1960 to 1963, the County of Barrhead removed brush from the lower reaches of the Paddle River. In 1962, the Prairie Farm Rehabilitation Administration (PFRA) studied the flooding problem and in its 1966 report pointed to the technical feasibility of providing physical works such as storage reservoirs and channelizations as a means to providing a degree of flood protection. In 1968, the Provincial Government reiterated its assistance offer to the counties for channelization and cutoffs.

The Department of Environment was formed in 1971 and formulated a three stage approach to tackle the serious flooding problems of the Paddle River Basin. Stage 1, consisting of brush removal from the channel, was undertaken in the winter of 1971-72 and achieved a measure of immediate flood relief. Stage 2,

consisting of channelization, commenced in 1972 and is still in progress. Stage 3, calling for flood storage reservoirs, has not been implemented, but is still under active investigation.

A comprehensive study, completed in 1974 by Alberta Environment within the framework of Stage 3, concluded that a combination of three reservoirs Site 7 on the Paddle River, Site 5A on the Little Paddle River, and Site 3B on Connor Creek, in addition to channelization through the flood plain could provide protection against a flood having a 1 in 25 year return period. This system is described in information Bulletins 1 to 4 of the Environment Conservation Authority (ECA) and was presented to the Basin residents and the public by the ECA during formal hearings in January, 1975, During these hearings many diverse options concerning the flood problems and proposed remedial measures were expressed.

In March, 1975, the ECA issued a report and recommendations with regard to flood control and water management in the Paddle River Basin. The Authority drew certain conclusions from the hearings and made some general as well as specific recommendations.

In order to resolve the difficulties, reconcile the differences, and arrive at flood control measures generally acceptable to the Basin residents, the ECA recommended that two committees, a Citizen's Advisory Committee and an Interdepartmental Management Committee, be formed.

The staff of Alberta Environment examined and responded to each of the recommendations of the ECA (July, 1975) and also developed three options as to how the Department could proceed in light of those recommendations and sentiments expressed by the public. Those three options were presented to the Government for a decision.

The decision was announced in a press release from the office of the Honourable Dr. Hugh M. Horner in 1975 and represents Government policy within the normal operational and budgetary constraints.

It should be noted that the decision implicitly recognized that in spite of the ECA hearings and subsequent recommendations, the issues were still unclear. The Government established the two committees as recommended by the ECA to tackle the problems with a view of resolving outstanding issues and developing flood control measures that would reasonably reflect the needs and wishes of the Basin residents. This decision also authorized continued channelization and further investigations of certain specific damsites.

In line with the ECA recommendations, the formal vehicle for public input was the Paddle River Advisory Committee comprising eleven Basin residents. As such, that Committee was readily accessible to all residents and the public at large. Its broad purpose was to seek local inputs, disseminate relevant information, and advise the Management Committee on the various important issues that arose from time to time. The Advisory Committee met regularly and held public information meetings in December, 1976 in Mayerthorpe and in January, 1977 in Barrhead.

The overall direction of implementing the Government decision was with the Interdepartmental Paddle River Basin Land Use and Water Management Committee, comprising the senior staff of the Departments of Energy & Natural Resources; Agriculture; Municipal Affairs; Recreation, Parks and Wildlife; Transportation; and Environment and the Edmonton Regional Planning Commission, as recommended by the ECA.

This Committee, in accordance with the Government decision and in consultation with the Advisory Committee, in 1976, authorized four more detailed investigations of topics related to the Paddle River flooding problem: further engineering of damsite 7 on the Paddle River by Environment, a fish habitat study of the Paddle River by Recreation, Parks and Wildlife, a watershed management study of the Upper Paddle River Basin by Energy & Natural Resources, and an evaluation of flood-free crossings by Transportation. Immediately upon completion, reports on the first three studies were released by Management Committee for "Discussion Purposes Only" in the summer of 1977. The flood-free crossing study was conducted directly by Alberta Transportation in conjunction with the Counties of Lac Ste. Anne and Barrhead.

All studies and materials generated during the project were made available to the general public in three "information centres" located in the Basin.

These four main investigations were consolidated by the Management Committee into a land use and water management program for the Paddle River Basin consistent with the spirit of the policy decision announced in October, 1975. The program features appropriate watershed management practices, alternative structural flood control works, and other related measures.

The Advisory Committee distributed four information supplements to all residents of the Basin outlining the history of the issue, a summation of the studies, the composition of the committee, and the decision-making process.

Public involvement was welcomed in two concluding information meetings in Mayerthorpe and Barrhead. A bi-county workshop afforded directly affected members of the public an opportunity to make an impact on final recommendations of the Advisory Committee."

The approved water management strategy is described below by Hurndall (1979).

"A two-component structural flood control system consisting of a multi-purpose reservoir at Site 7 on the Upper Paddle River and completion of the present channelization and dyking program within a five year period (from 1978) to achieve the 1 in 8 year summer flood protection at a cost of $17.5 million (1978), was accepted.

The multi-purpose uses of the reservoir at Site 7 would primarily be:

a) Flood control.
b) Water supply for Town of Mayerthorpe.
c) Downstream erosion control.
d) River flow augmentation and water supply for the Town of Barrhead.

In addition, the reservoir could also enhance:

e) Fish & Wildlife habitat.
f) Water-based recreation.
g) Future power generation potential.

Channelization Work

The channelization work including the construction of cutoffs and dyking commenced in 1972 and is still in progress to his date. Channelization and dyking to provide protection against the 1 in 8 year summer flood should be completed in 1982.

Paddle River Dam

A dam on the Paddle River is scheduled to be started during 1981. Site 7 has been chosen as the preferable location". (Hurndall 1979).

The dam was completed in 1985. Details are provided in Table 1.

Table 1

ENGINEERING SPECIFICATIONS OF THE SITE 7 DAM

Flood Control Works	
Reservoir	
- Size	43 x 10^6 m^3
- Area	350 ha
Dam	zoned earthfill
Downstream Channel Capacity	57 to 113 m^3/sec
Level of Protection	summer flood
Hydrologic Data	
1:8 year summer flood	
- peak	77 m^3/sec
- volume	27 x 10^6 m^3
Probable Maximum Flood	
- peak	858 m^3/sec
- volume	163 x 10^6 m^3

Source: Paddle River Dam Site Information Display

3. CLIMATE, TOPOGRAPHY AND FLOODING

The following description of the relationship between climate, topography and flooding in the Paddle River Basin is from the 1981 Alberta Environment report River Forecasting for the Paddle River by Kuhnke and Mustapha.

> *"The headwaters in the western end of the basin reach a maximum elevation of about 1000 metres above mean sea level. The topography of the headwaters is hilly and much of the land is forested with a mixture of deciduous and coniferous trees. Some of the area has been cleared for cultivation. The major tributary in the headwaters is the Little Paddle River.*
>
> *The lowest areas of the basin are at approximately the 600 metre elevation. The major tributaries below the confluence of the Paddle and Little Paddle Rivers are Connor Creek and Thunder Creek. These tributaries originate in the northern part of the watershed where the land is hilly and lakes of various sizes are the dominant hydrological feature. Most of the area is under cultivation.*
>
> *The headwaters and the floodplain of the basin can be differentiated on the criterion of channel slope. Above the confluence of the Paddle and Little Paddle Rivers, the Upper Paddle River has an average slope of about 0.0014 metres/-metre while the Little Paddle slope is about 0.0011 m/m. Below the confluence the slope flattens quickly to about 0.00018 m/m which is only about one seventh the slope of the headwaters channels. This rapid change in the slope of the river channel is one of the key reasons for the flooding problem in the basin.*

There is a broad floodplain which stretches almost all the way from the confluence of the Paddle and Little Paddle to the town of Barrhead near the mouth of the river. This floodplain, as a result of frequent inundation, is extremely fertile and therefore supports considerable agricultural activity. Most of the flood damage takes place in the floodplain, the greatest proportion of the damage being agricultural with damage to residential property much less significant in terms of economic loss.

The climate of the Paddle River Basin is continental, temperate and cool. Weather patterns in the basin are not directly subject to the influences of large bodies of water or mountainous terrain. The average annual precipitation for the area ranges between 440 and 520 millimetres with the greater amounts falling in the headwaters of the watershed. Snowcover is prevalent in the basin from November to April in most years.

The annual hydrological behavior of the basin is usually characterized by a single streamflow peak as a result of snowmelt, and one or more peaks during the summer resulting from moderate and heavy rainfall events. The snowmelt flood season usually falls in April, while the prime time for summer floods occurs between the middle of May and the beginning of August.

Causes of Flooding in the Paddle River Basin

Flooding occurs in the Paddle River Basin primarily because the river channel through the floodplain is not capable of passing the runoff generated in the headwaters areas at a fast enough rate. The dramatic flattening of channel slope downstream of the confluence of the Paddle and Little Paddle Rivers causes streamflow generated in the headwaters to slow down, and this decrease in velocity causes the river levels to rise. The

natural river banks below the confluence are quite low and once these banks are overtopped, the water spreads quickly over the broad floodplain.

Changes in land use within the last century are generally held responsible for aggravating the flood problem in the watershed. It is believed that the clearing of the land for cultivation or pasture has allowed greater volumes of runoff to occur.

Runoff which produces flooding originates from either of two major sources: snowmelt from a heavy spring snowpack, or heavy widespread rainfall of a duration of one day or more. Historically, the largest floods have resulted from snowmelt, although the greater number of floods have been due to heavy rains.

1. Snowmelt Floods

The volume of runoff from snowmelt is dependent upon such factors as the water equivalent of the snowpack immediately prior to the melt period, the intensity of the melt (which in turn depends on a number of meteorological conditions such as temperature and solar radiation), and the soil moisture conditions established before freeze-up the preceding autumn.

In the spring of 1974, a record volume of snowmelt runoff occurred because of the worst possible combination of these factors: a wet autumn in 1973 followed by twice the normal amount of snow during the winter of 1973-74, and a melt period that was delayed until the last week of April. The result was that an abnormally high percentage of the water in the snowpack reached the river channel. In a normal year, about 50 percent of the water in the snowpack might contribute to streamflow with the remainder being trapped by the soil or being lost to evaporation.

The average April 1st snowpack water equivalent for the Paddle River is about 70mm, so that the normal snowmelt runoff would about 35 mm. In 1974, snowpack water equivalent (basin average) was about 200 mm. In that year, the percentage of snowpack runoff was about 80 to 95 percent. The corresponding runoff depth of 160 to 190 mm was approximately four to five times the normal runoff.

2. Rain-Produced Floods

Most of the floods which occur on the Paddle River are a result of heavy widespread rainfall occurring in the headwaters over the period of a day or more. Storms of this variety can occur during any of the summer months, however the probability of occurrence is greatest during June and July. The factors affecting runoff from rainfall are basically the intensity, areal extent and duration of the rainfall, and the soil moisture conditions prior to the storm. For example, a rainstorm of given intensity, duration and areal extent will probably produce more runoff early in the summer when soil moisture levels are high than in late summer when soil moisture levels are usually lower. As a second illustration, thunderstorms may produce extremely intense rainfall but are usually of short duration and affect relatively small areas of the watershed, and therefore do not produce large flood runoff volumes.

Runoff Characteristics of the Paddle River Watershed

1. During the large snowmelt runoff event of 1974, although most of the runoff volume was produced by the Lower Paddle, the three main areas of the basin contributed runoff depth more or less equally. During the moderate snowmelt runoff event of 1979, the Upper and Little Paddle watersheds contributed significantly more runoff depth than the Lower Paddle, and

the runoff volume contribution of the Lower Paddle became less significant than in 1974. It is generally the case that the heavier the basin snowpack, the more significant the Lower Paddle watershed becomes during the spring snowmelt.

2. *The Upper Paddle watershed usually contributes a higher proportion of the runoff volume from rainfall than either the Little Paddle or Lower Paddle. In the case of the Little Paddle, this is primarily because the Upper Paddle has a larger drainage area. In the case of the Lower Paddle it is because the rainfall is generally heavier in the headwaters and because a greater percentage of runoff is generated from the rainfall in the Upper Paddle due to the slope of that watershed.*

3. *During the July 1979 event, the Lower Paddle received considerably more rainfall than the headwaters areas and generated an exceptionally high proportion of the total runoff volume with the depth of runoff being of the same order of magnitude as the other two watersheds. This event illustrates that there are instances when rainfall runoff from the Lower Paddle may be significant in the flooding of the Paddle River."*

Table 2 shows the variability of stormflows in terms of flow rate and time of occurrence. The influence of climate is easily seen when the maximum mean daily flow rates in 1965 and 1967 are compared. The flows differ by a factor of 13.

Table 2

ANNUAL MAXIMUM MEAN DAILY DISCHARGES FOR
THE UPPER PADDLE AND LITTLE PADDLE RIVERS 1963-1984

Year	Upper Paddle River near Rochfort Bridge (674 km^2)		Little Paddle River near Mayerthorpe (321 km^2)	
	Maximum Mean Daily Flow Rate in m^3/s*	Date of Peak Flow	Maximum Mean Daily Flow Rate in m^3/s*	Date of Peak Flow
1963	50.70	April 16	32.08	April 16
1964	14.00	May 7	6.06	May 7
1965	122.00	June 28	66.30	June 28
1966	30.60	April 2	14.00	April 1
1967	9.03	May 8	5.80	April 25
1968	11.80	May 7	7.14	May 7
1969	39.60	April 11	16.30	April 12
1970	20.10	July 19	7.22	April 15
1971	73.60	July 12	63.40	July 11
1972	36.80	June 26	17.80	June 26
1973	31.10	June 25	14.60	June 26
1974	88.10	April 19	48.70	April 18
1975	37.10	June 29	30.60	June 29
1976	13.50	April 7	4.93	April 7
1977	75.30	May 30	37.90	May 29
1978	66.00	July 11	18.30	July 12
1979	35.70	April 25	26.30	July 12
1980	42.50	June 18	26.70	June 18
1981	38.00	June 2	5.48	March 15
1982	36.90	April 25	31.00	April 23
1983	27.60	July 10	29.20	July 9
1984	14.10	June 10	16.50	June 8

SOURCE: Water Survey of Canada - Surface Water Data

NOTE: *Units are cubic metres per second (m^3/s)

4. WATERSHED MANAGEMENT STUDY - 1977

In 1975 the Environment Conservation Authority (ECA) made several recommendations upon completion of the public hearings into flood control and water management in the Paddle River Basin. Two significant recommendations were:

1. *"That flood control be sought through less costly, more complex integrated land use and water management alternatives (they recommended that proposed storage reservoirs on Connor Creek and the Little Paddle River be deferred indefinitely).*

2. *That integrated land use and water management programs be sought for the Basin as a whole, whose objectives will be to improve the productivity of the Basin and minimize hazards arising from spring and summer floods, (they recommended that a reservoir be constructed in the upper reaches of the Paddle River as a first step in this program)"*, (Alberta. Energy and Natural Resources 1977).

At the direction of the Land Use and Water Management Committee (LUWMC), Alberta Energy and Natural Resources (ENR) carried out a study of possible flood control measures through land use (watershed) management practices in the Paddle River headwaters. The findings of the study are contained in A Study of Watershed Management Options for Controlling Flood Runoff in the Headwaters of the Paddle River Basin (Alberta. Energy and Natural Resources 1977). The report shows that proper vegetation and land management in the headwaters of the Paddle River offer a good opportunity to control increases in the frequency and magnitude of flooding, but cannot prevent flooding. The report recognizes that not all areas within the headwaters contribute equally to runoff or at the same rate, thus areas of high, moderate and low response were identified.

4.1 Hydrologic Response Zones

4.1.1 Critical Zone

Lands in the critical zone have the greatest potential for contributing to flood runoff. This zone includes the major source areas of streamflow in the headwaters.

4.1.2 Marginally Critical Zone

The following lands contribute less to flood runoff and are represented in this zone:

a) lands within 200 m of designated source areas; and

b) lands with slopes generally greater than five per cent.

4.1.3 Non-Critical Zone

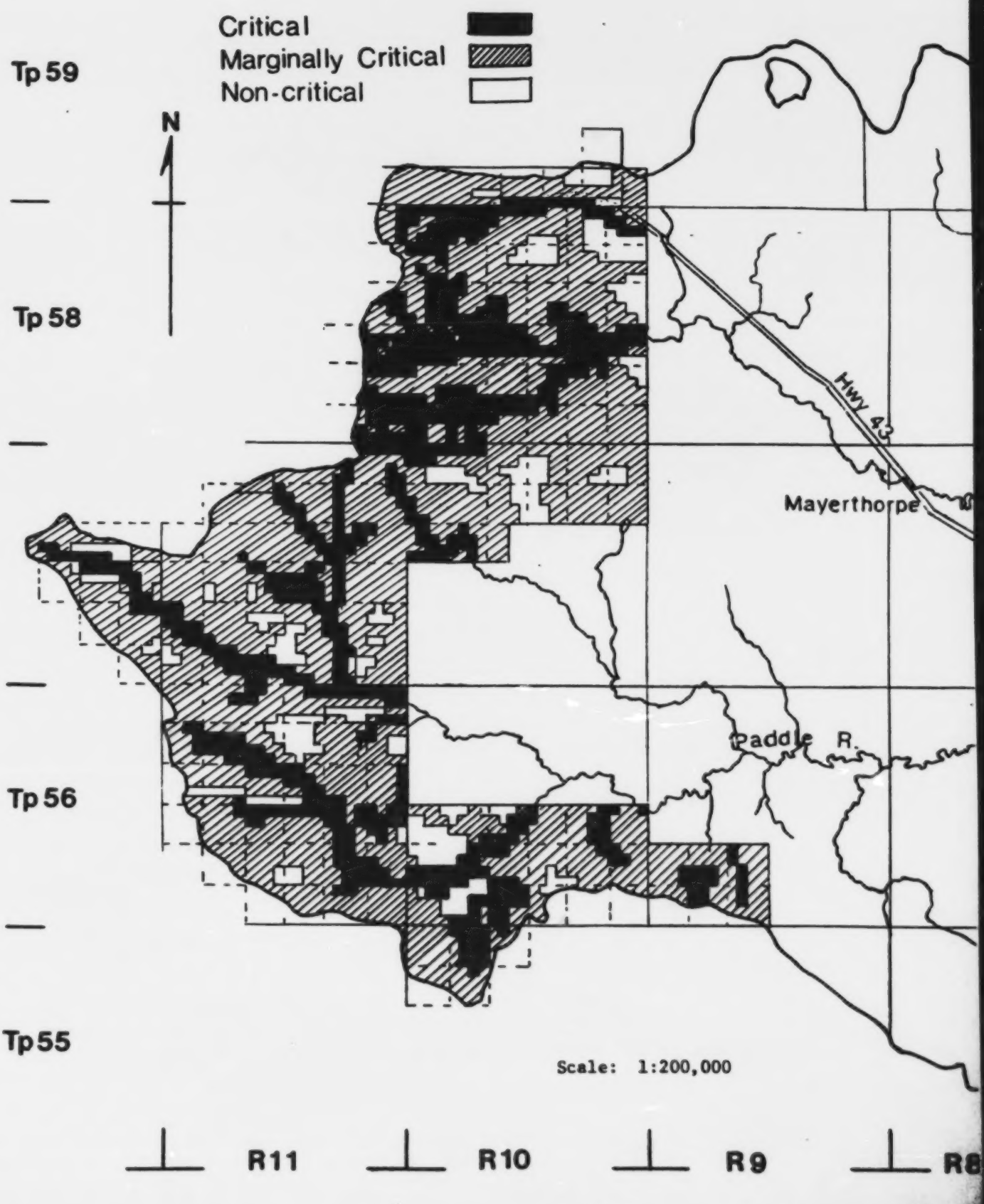
Lands in this zone are considered to have the lowest potential for contributing to flood runoff. They occur on slopes less than five per cent, and are located greater than 200 m from a designated source area.

These zones are shown in Map 2.

The LUWMC used the findings of the report to develop eight land use recommendations, which form the basis of the land management strategy for the headwaters area. The recommendations are discussed in detail in Chapter 5.

The report demonstrated the need for controlling permanent and temporary vegetation removal and the need for land use practices that are practical and compatible with runoff and flood damage control.

MAP 2 Hydrologic Response Zones



The ECA recommendations were the first steps in the development of a complementary water and watershed management program for flood control.

4.2 Water Management

> *"Water management consists of the development, processing, storage and transportation of water for agricultural, industrial, recreational and domestic uses. Examples of water managers are sanitary engineers, irrigation specialists, flood control and reservoir managers"* (Hewlett 1982).

The water management practices carried out to date are construction of a flood control dam in the Upper Paddle River, channelization and brush removal. Water management is the responsibility of Alberta Environment.

4.3 Watershed Management

> *"Watershed management is ....the management of the natural resources of a drainage basin primarily for the production and protection of water supplies and water-based resources, including the control of erosion and floods, and the protection of esthetic values associated with water"* (Hewlett 1982).

All land users affect the hydrology of a basin and thus each user has the potential to be a watershed manager. Examples of watershed managers are foresters, farmers, ranchers, agriculturalists and loggers. Watershed management in the Green Area (forest lands not available for agricultural development other than grazing) is the responsibility of the AFS.

The remainder of this report describes watershed management practices of the AFS in the Paddle River headwaters.

5. SUMMARY OF LAND MANAGEMENT RECOMMENDATIONS

In 1978 the Paddle River Basin Land Use and Water Management Committee (comprising senior government staff) made recommendations for controlling flooding in the Paddle Basin. The recommendations formed the policy base for the engineering and land use programs implemented in the Paddle Basin. The recommendations were based on the findings of several studies into flood control possibilities in the basin and incorporated the advice of the Citizen's Advisory Committee which was made up of 11 basin residents whose function was to provide liaison between government planners and basin residents.

The recommendations and rationale are described below.

5.1 Recommendation 1 - Land Clearing Management

"The amount of land clearing in the headwaters of the Paddle River Basin should be limited to assist in minimizing future increases in flood run-off."

RATIONALE

As explained in section 4.1, the headwaters area has been zoned into three hydrologic units with differing degrees of flood generation potential. It is essential to control land clearing in the critical zone and to a lesser extent the marginally critical zone.

The critical hydrologic response zone covers that part of the watershed known as the source area. Source areas are those parts of a watershed that contribute directly to streamflow.

The source area is variable in size and location. This accounts *"for the fact that neither stormflow or baseflow is uniformly produced from the entire surface or subsurface of a basin. Instead the flow of water in a stream at any given moment is under the influence of a dynamic, expanding or shrinking source area, normally representing only a few percent of the total basin area.*

Whether the water remains in the soil to feed baseflow and evapotranspiration or re-emerges quickly to become stormflow, depends upon the depth and porosity (the dynamic storage capacity) of the soil mantle. Storage capacity is limited where the water content of the soil is approaching saturation and where layers of restricted conductivity exist close to the soil surface. The stream surface, channel banks and surrounding seep areas, and zones of restricted conductivity are the main sources of stormflows. Except in regions of critically shallow soil mantles, only extreme rainstorms exceed the dynamic storage capacity of forested watersheds.

The area actively involved in producing stormflow will vary from less than 1% of the basin during small storms to more than 50% in extreme storms. Cultivated fields, heavily grazed pastures and roadways become a part of the variable source area for stormflow whenever they discharge directly to stream channels" (Hewlett 1982).

As a storm proceeds it is possible that parts of the marginally critical zones could become source areas for stormflow.

The question remains, why retain these areas in forest cover? The answer is in four parts as noted by Hewlett (1982):

a) ***"Forest cover holds soil in place."***

Eroded soil materials in a creek (i.e., suspended sediment) can aggravate flooding problems downstream. As water slows down, sediments settle out of suspension. The buildup of sediments and debris can slowly fill reservoirs, elevate channels and cause the channel to cut new paths through the flood plain.

b) ***"Forest cover provides additional soil water storage potential."***

Evapotranspiration from most forests generally exceeds that of other types of cover. The effect of evapotranspiration is to dry soils, thereby maintaining or increasing soil water storage capacity. By maintaining as much soil moisture storage capacity as possible in source areas, it is possible to retain significant quantities of water in the soil mantle as opposed to releasing this water quickly to streamflow. Once the soil moisture storage capacity is exceeded, water is diverted to surface streamflow. This is the case during large flood flows where soil storage usually is full and the vegetative cover is only useful for reducing soil erosion.

c) ***"Forest cover maintains infiltration."***

The infiltration of water into the soil is generally faster in undisturbed forest than under cultivated conditions. If the forest is quickly regenerated, the infiltration capacity of the forest soil will not be impaired. If the forest is cleared and the land is converted to another use such as agriculture, the infiltration rate and capacity of the soil can be significantly reduced. Where intensive grazing takes place, soils are often compacted and litter is reduced, particularly where land is cleared for forage production.

"Vegetated land is generally more absorbent because surface litter reduces raindrop impact effects, and organic material, microorganisms, and plant roots tend to increase soil porosity and stabilize soil structure. Vegetation also depletes soil moisture to greater depths, increasing the water storage opportunity and favoring higher infiltration rates; these effects are more pronounced under forest cover where roots penetrate deeper and evapotranspiration rates are greater. Infiltration capacity generally increases with the cover-type sequence from:
bare soil —>row crops-->grain-->pasture-->meadow-->forest"
(Lee 1980).

d) *"Forest cover favors granular soil frost as opposed to concrete frost."*

"Forest cover, litter, and lower vegetation also moderate soil microclimate, in particular the depth and frequency of soil frost; infiltration can occur in frozen soil if the large pores are not filled with ice, but when saturated soils freeze they become impermeable" (Lee 1980).

Concrete frost development is more common in cultivated fields than in forests. Concrete frost occurs in frozen, saturated soil layers which may not contain pores through which water can move. This can result in surface flow during snow melt.

Even though it is not possible to quantify exactly the flood control value of each of these four principles, the need for retaining a stable forest cover in source areas is evident. It should also be noted that forests can neither cause nor prevent major floods. Large floods are mostly attributed to climatic events, not land use practices. On the other hand, the damage done by the flood can be very much a result of land use.

The impact of land use on flooding is mainly due to changes in soil water storage capacity. Once soil water storage capacity is full, the effects of land use on the volume of flood flow are obscured by climatic events. The loss of storage capacity through land use may contribute to a greater frequency of a given size of flood event. For example, the 10-year event may become the five, six or seven year event. That is, the size of flow that would have occurred on average every 10 years before land clearing, may now occur every five to seven years on average after land clearing.

5.2 Recommendation 2 - Land Sales

"No public lands in the headwaters, other than those currently committed for sale, should be removed from public ownership."

RATIONALE

It is important that land use is controlled and consistent with flood control strategy. Removal of lands from crown to private ownership removes that control.

5.3 Recommendation 3 - Land Purchase by the Crown

"The government should offer to purchase any patented lands offered for sale in the Critical Zone of the headwaters area. Consideration should be given to purchasing lands offered for sale in the Marginally Critical Zone according to individual merit."

RATIONALE

As described under recommendation two, this will allow more consistent land management.

5.4 Recommendation 4 - Referrals

"Referral systems including government agencies and, where appropriate, input from local Agricultural Development Committees, should be utilized to review proposed dispositions of public lands, proposed purchases of patented lands by the government, and future use of lands purchased."

RATIONALE

The Forest Land Use Branch of the AFS administers a reservation which requires that all land use development proposals are forwarded to the Watershed Management Section for approval for those crown lands listed in Appendix 1 and shown on Map 2.

5.5 Recommendation 5 - Fire Protection

"Fire protection by the Alberta Forest Service should continue to be given high priority in the headwaters area."

RATIONALE

Fire can have serious short-term effects on infiltration, evapotranspiration and soil erodibility. A major fire followed by a flood-producing storm could greatly increase flood damage potential. Anderson, Hoover and Reinhart (1976) state that *"Wildfire that consumes the forest floor and kills the trees and other vegetation over a large area has major impact on stormflows, erosion, sedimentation and the quantity of streamflow."*

5.6 Recommendation 6 - General Land Management Practices

"Land management practices on public and patented lands should be compatible with runoff control, especially in the headwaters area. The economics of farming operations must be recognized in applying this recommendation to private and currently leased lands.

a) Lands disturbed by the construction of roads, seismic lines, pipelines, etc. should be quickly and effectively revegetated to minimize overland flow and sediment production.

b) Special controls should be placed on any future timber harvesting operations in the headwaters area, e.g. location and size of cutblocks, control of soil disturbance, revegetation of roads, and rapid reforestation of cutover areas.

c) Public lands that should be reforested or otherwise reclaimed to improve watershed condition should be identified and the necessary action undertaken by the government.

d) Special attention should be given to range management practices on grazing lands to ensure that soils do not become compacted as a result of over-stocking or poor distribution of livestock , particularly in the Critical Zone. Land clearing on leases and reserves should also be subject to special management practices."

RATIONALE

a) As previously stated, vegetation remains the most effective erosion control measure available.
b) This section will be discussed in detail in Chapter 7.
c) As stated. Some minor work has been done.
d) As stated. See 6.1.3

5.7 Recommendation 7 - Alberta Agriculture Land Management Practices

"Basin farmers and residents must recognize the importance of terracing, contour cultivation, cropping practices, and range management practices in controlling flooding and flood damage. Assistance in implementing these kinds of practices should be offered by Alberta Agriculture."

RATIONALE

The practices of terracing, contour cultivation, strip cropping, crop rotation and improved range management on appropriate flood plain lands will slow the movement of water from these areas to nearby stream channels.

No formal project has been implemented.

5.8 Recommendation 8 - Connor Creek Grazing Reserve

"With respect to the Connor Creek Grazing Reserve:

a) It is recommended that future land clearing in the area comprising the headwaters of Connor Creek be restricted with respect to area and location so as to minimize the potential for increasing flood runoff.

b) It is recommended that additional land clearing be permitted in the Romeo Creek portion of the reserve, but under the condition that no clearing of lands in the critical hydrological response zone be permitted."

RATIONALE

See recommendation 1 rationale discussion.

6. LAND MANAGEMENT PRACTICES FOR SPECIFIED RESOURCE USES

The following outlines management strategies for each major land use in the headwaters area. These conditions apply to those crown lands listed in Appendix 1 and shown on Map 2.

6.1 Grazing

6.1.1. Management Intent

The intent of grazing management is to maintain good range condition by regulating the number and distribution of cattle and to control land clearing for grazing development to ensure that soils do not become compacted, drainage channels are not damaged and land clearing takes place only on stable areas which are not, nor will become source areas for stormflow.

6.1.2 Major Issues

Grazing can result in soil compaction and channel damage leading to increased stream sedimentation and possibly to overland flow. Clearing land for pasture increases the amount of water available for streamflow and can reduce the delivery time of water moving to surface channels.

6.1.3 Management Guidelines

1. All current grazing dispositions will be honored.

2. Unimproved grazing licenses can be issued for all zones.

3. Range improvements that improve cattle distribution and range utilization are encouraged.

4. Grazing development may be integrated with other resource developments such as timber harvesting.

5. The size and amount of clearing in the non-critical zone (Map 2) is subject to site conditions and other resource use restrictions.

6. Land clearing for grazing in the marginally critical zone (Map 2) will be considered on a site-specific basis. The amount and location of clearing in this zone will be restricted to relatively flat areas located away from drainage channels and will follow appropriate landform features. This guideline should keep the amount of land cleared in this zone to under one-third of the total zone area. Grazing development guidelines should be reviewed if total clearing significantly exceeds one-third of the zone.

The following management guidelines for grazing were established by the AFS and Public Lands Division in 1978 as part of the implementation of the LUWMC recommendations.

1. *"Grazing permits and grazing leases should be phased out in the headwaters study area and replaced by Forest Grazing Licenses. FGL provides the best opportunity to co-ordinate grazing with the objective of reforesting or otherwise reclaiming public land to improve watershed condition and will help to ensure proper range management. They are administered under the Public Lands Act and no administrative changes are required in regard to processing applications and renewals.*

All new grazing dispositions should be FGLs. It is understood that for existing lease holders transition would be made, with consent, over the longer term as leases come up for renewal or assignment, and as additional land is applied for.

FGLs should be issued for 1- to 10- year periods. Where grazing leases having longer terms are up for renewal, the license should be issued for a term not exceeding ten years."

Comments

Leases are no longer being converted to licences because of recent policy changes regarding FGLs.

New dispositions are still being issued as licences (FGLs).

2. *"No range improvement requiring the clearing of land or soil disturbance should be permitted within critical hydrologic response zones.*

3. *Decisions to allow range improvement in marginally critical and non-critical hydrologic response zones should be based on a review of the requirements outlined in each request and watershed management concerns. The Forest Land Use Branch Watershed Management Section should be consulted on any land improvement requests.*

4. *The on-off dates for livestock should be made June 1 and October 31 respectively for all grazing lands in all hydrologic response zones within the headwaters study area.*

5. *Range inspections should be made annually at the end of each grazing season. Watershed condition, carrying capacity and stocking rates should be emphasized.*

6. *In regard to the Connor Creek Grazing Reserve, it was agreed that close co-operation between the Grazing Land Management Section and Watershed Management Section of the Alberta Forest Service throughout the phases of development would help to ensure minimal impact."*

6.2 Agricultural Developments Other Than Grazing

6.2.1 Management Intent

Agricultural developments other than grazing will be considered on lands in the White Area which are suitable for development and not erosion prone or which are or could become source areas for stormflow.

6.2.2 Major Issues

The clearing and breaking of land for agricultural development leaves the ground unvegetated for portions of the year and thus subject to erosion by wind and water and also susceptible to concrete frost formation.

6.2.3 Management Guidelines

1. No public lands will be sold for agricultural development in the White Area.

2. Green Area withdrawals will not be approved for agriculture or residences.

3. No agriculture disposition requiring land clearing or soil disturbance will be allowed in the critical zone.

4. Farm Development Leases and other forms of agricultural lease or agreement to use Crown land must be approved by the Forest Land Use Branch.

6.3 Oil and Gas Exploration and Development and Linear Clearings

6.3.1 Management Intent

Petroleum exploration and development and other linear developments will be managed to control the extent, location and impact of land clearing in order to control flood water generation and water quality deterioration.

6.3.2 Major Issues

Linear developments cross many watercourses creating point sources for sediments entering a channel. Linear developments such as roads and seismic lines also intercept subsurface drainage and can become new intermittent channels which may move water more rapidly and directly to the creeks. This can increase flood flows. The permanent removal of forest for roads, wellsites and other clearings can also increase surface runoff.

6.3.3 Management Guidelines

1. Maximum protection will be given to the land and water resources through the use of letter of authority operating conditions and careful inspection of these activities by field staff.

2. Hand-cut seismic lines must be used within a minimum of 45 m of any watercourse.

3. Stream crossing plans must be prepared by disposition holders and should be discussed with and approved by AFS field staff prior to construction.

4. Reclamation and revegetation should proceed concurrently with construction and development. Revegetation should be completed by the end of the first complete growing season following construction.

5. Within the critical zone, clearings should be kept to the minimum possible to permit construction of facilities and operations.

6.4 Coal Exploration and Development

6.4.1 Management Intent

As with all resource developments, coal mining may be allowed if water quality deterioration and flood aggravation can be held to acceptable levels.

6.4.2 Major Issues

The reported impact of strip mining on peak flows and flood volumes varies from reductions to very significant increases in stormflow. This variability depends on basin and soil physical characteristics, climate, time of year and the nature of the mining practice employed. Bryan and Hewlett (1981) have shown that large winter stormflows after surface mining forest land in Eastern Kentucky were probably reduced, while small stormflows (usually in the summer) were increased. Hewlett (1982) states,

> ***"The reason for the decrease appears to be that changes in the depth and arrangement of the earth mantle during mining tended to provide greater water storage capacity in the mantle. The increase in small stormflows was probably due to greater summer rainfall intensity on expanded rills and gullies in the mine spoil."***

The increased stormflow was recorded for small, generally insignificant storms which were not a flood threat. What is important as pointed out later by Hewlett (1982) is ***"It is, of course, well known that sediment export from stripped areas is increased hundreds of times or even more."***

Mining in source areas can result in significant stream sedimentation particularly since *"very little runoff water is required to keep sediments moving off erodible surfaces near stream channels"* (Hewlett 1982).

6.4.3 Management Guidelines

1. The surface mining of coal is not allowed in the critical zone and is restricted in the marginally critical zone. Forest Land Use Branch approval is required for all developments.

6.5 Other Land Uses

This category covers all other land uses not previously discussed. Examples are gravel pits, landfills and recreation developments.

6.5.1 Management Intent

All land use activities must be consistent with management strategies for flood control and water quality protection.

6.5.2 Major Issues

All surface disturbances have the potential to cause water quality deterioration and aggravate flooding.

The cumulative effect of many seemingly minor developments can be significant.

6.5.3 Management Guidelines

All proposed land uses in the headwaters must be approved by the Forest Land Use Branch. Since these types of developments are anticipated to be infrequent and minor in extent, specific guidelines have not been developed. Development conditions will be provided through the reservation referral system.

Table 3
MATRIX OF MANAGEMENT GUIDELINES BY RESOURCE

RESOURCE	HYDROLOGIC RESPONSE ZONE		
ACTIVITY	CRITICAL	MARGINALLY CRITICAL	NON CRITICAL
1. GRAZING			
. land clearing	X	R	A
. improved grazing no clearing	A	A	A
. new grazing licenses (unimproved)	R	A	A
2. AGRICULTURE			
. clearing and breaking	X	R	R
. Green Area withdrawals	X	X	X
3. OIL AND GAS/LINEAR			
. seismic activity	R	R	A
. facility development	R	R	A
4. COAL			
. surface development	X	R	R
. exploration	X	R	R
5. OTHER LAND USES	R	R	R
6. TIMBER HARVESTING	R	R	A
7. LAND SALE	X	X	X

X Not Allowed
A Allowed - normal operating guidelines and procedures apply
R May be Allowed - additional restrictions may apply; possibly not allowed

7. TIMBER MANAGEMENT POLICY

7.1 Why Cut the Forest?

The timber management policy in the Paddle River headwaters is based on the conclusions of research into the interaction of forest land use and climate on flooding. Some of these findings are described in Appendix 2.

To prevent increases in flooding, AFS watershed managers recommended that the *"location and extent of land clearing"* be controlled and that *"this objective can be achieved to a large degree by retaining the maximum amount of forest cover in the critical hydrologic response zone"* (Alberta. Energy and Natural Resources 1977).

The maximum amount of forest cover is the point where a stand of trees is making full use of the available energy and water supply. At this point, evapotranspiration will be at a maximum and provide the greatest soil water storage opportunity or flood mitigation possible. Full hydrologic use of a site is usually achieved by a vigorous healthy stand of trees throughout much of the lifetime of that stand. As trees mature and die, full occupancy of the stand can be reduced depending on species and regrowth.

Much of the Paddle River forest is composed of the hardwood species trembling aspen (Populus tremuloides Michx.) and balsam poplar (Populus balsamifera L.). These species are generally susceptible to an endemic fungus, hypoxylon canker (Hypoxylon pruinatum). The incidence of this fungus is generally high in mixed wood stands as is tent caterpillar (Malacosoma disstria) infestation.

A sign of fungal attack is reddish-brown infection in the bark in the early stages. As infection spreads, the tree may be girdled. Conks appear in the late stages usually indicating decay of the wood and loss of tree vigor, thereby potentially reducing hydrologic utilization. Infected trees should be removed to allow the establishment of new growth.

In the headwaters and surrounding area there is a strong demand for trembling aspen from commercial users, and for coniferous timber from local users.

With careful planning, utilization of the timber resource can meet timber management and watershed management objectives.

7.2 How Long Will it Take the Forest to Recover After Harvest?

Full hydrologic recovery (the point of full water and energy use) is expected within 20 years of harvest for hardwood species and not before 30 years for conifers. These are conservative estimates based on research throughout North America and Europe.

Poplars reproduce both sexually and asexually. When a poplar is felled or severely stressed, suckers rapidly sprout from the roots and stump. This ensures prompt revegetation and rapid hydrologic recovery.

The main difference between timber harvesting and other forms of land clearing is that timber harvesting promotes forest regrowth while most other land uses, such as row crop production, usually require the suppression or eradication of forest regrowth. In Alberta, regulations require that lands managed for timber production be revegetated to AFS stocking standards within 10 years of harvest. Poplars usually regenerate quickly without any assistance.

7.3 What Do We Want The Forest To Look Like?

Ideally, the forest should contain a good mix of timber of various age classes and species, spread throughout the managed area. This reduces the potential for damage from disease and fire, stabilizes wood supplies and diversifies wildlife habitat.

The merchantable timber is scattered throughout the headwaters. No large concentration of merchantable types is present. This naturally dispersed pattern will help distribute the cut over the watershed. Poplars will be managed on a 60-year rotation while conifers will have an 80-year rotation.

7.4 What Are The Existing Timber Management Commitments?

1. Deciduous Timber Allocation

Two deciduous timber allocations (DTA) are held by Pelican Mills Ltd. for the rights to the deciduous (aspen) timber. Only aspen is being utilized, but improvements in harvesting and processing methods could result in the use of balsam poplar.

2. Miscellaneous Timber Unit

This unit is managed for local and small commercial uses of hardwood and softwood. The harvesting of this timber will be subject to operating conditions which will be discussed in section 7.5.

7.4.1 White Area

In the White Area, the forest is usually not replaced after harvest, since the land is often made available for sale. Since recommendation 2 prevents the sale of land, White Area lands should be reforested.

Grazing developments will be considered in conjunction with timber harvest planning in some cases.

7.5 What Are The Operating Conditions?

The Alberta Forest Service regulates timber harvesting through forest management plans, ground rules and operating conditions which are designed to protect the land, water, timber, esthetic and wildlife resources of a watershed. Each hydrologic response zone is managed differently because the flood generation potential varies from zone to zone.

Non-Critical Zone

Standard ground rules apply.

Marginally Critical Zone

1. Standard ground rules apply.
2. Cutblocks should be planned to distribute the cut as evenly as possible over the three aspect (orientation to the sun) classes: North, South, East-West.
3. When requested, the timber operator shall submit detailed 1:5 000 sketch maps for individual blocks which indicate:

    a) Location of roads, landings and main skid trails
    b) Skidding direction
    c) Locations and classes of streams
    d) Location, type and size of watercourse crossings
    e) Location of springs, seepages and water source areas
    f) Sensitive slopes and aspect
    g) Sensitive soils

Critical Zone

1. Standard ground rules apply with some additions.
2. At least two-thirds of the area must contain timber older than 20 years before further harvest is allowed.
3. When possible, timber should be removed equally from the three aspect classes: North, South and East-West.
4. Winter operations only including tree hauling.
5. See 3, in Marginally Critical Zone.

All timber harvesting operations will be developed in co-operation with Fish and Wildlife Division and other affected resource management agencies. Landscape logging will be considered where necessary for esthetic and recreation development.

8. CONCLUSION

1. Watershed management continues to have a valuable role in the integrated flood control program in the Paddle River headwaters. The recommendations and guidelines for watershed management presented in the report should remain in effect for an indefinite period to complement the structural flood control measures.

2. Research has shown that properly managed timber harvesting will not aggravate flooding and can be beneficial to flood control by maintaining a healthy forest environment.

APPENDIX 1

LANDS UNDER WATERSHED PROTECTION RESERVATION
IN
THE PADDLE RIVER HEADWATERS

The crown lands described below are held under a watershed conservation reservation by the Watershed Management Section, Forest Land Use Branch.

Generally, a PNT 0151.2.710.730 reservation is in effect. All applications for land clearing on the reserved lands are referred to the Forest Land Use Branch. Each application is evaluated with regard to the stated Paddle River flood and erosion control objectives, and may be approved as is, modified and approved, or not approved.

LAND DESCRIPTIONS

Twp.	Rge. W5M	Section
55	10	NW27, N 1/2 28, N 1/2 29, NE30, 31, 32, 33, NW34
55	11	NE34
56	9	NW5, SE8
56	10	W 1/2 3, 4, E 1/2 & NW5, W 1/2 & SE6, N 1/2 7, NW8, SE8, 9, W 1/2 10, 11, SW12, E 1/2 & SW18

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Twp.	Rge. W5M	Section
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55	11	NE34
56	9	NW5, SE8
56	10	W 1/2 3, 4, E 1/2 & NW5, W 1/2 & SE6, N 1/2 7, NW8, SE8, 9, W 1/2 10, 11, SW12, E 1/2 & SW18

Twp.	Rge. W5M	Section
56	11	1, 2, N 1/2 & SE3, NE4, N1/2 & SE8, 9, 10, 11, 13, 14, S 1/2 15, N 1/2 16, NE17, NE18, 19, 20, 21, 22, 23, S 1/2 24, N 1/2 25, N 1/2 & SE 26, 28, 29, 30, 31, 32, 33, 34, 35
57	10	19, S 1/2 & NE20, NE25, N1/2 & SW26, E 1/2 27, W1/2 28, 29, 30, 32, S1/2 33, E 1/2 34, W 1/2 & SE35, NW & SE 36
57	11	NW2, W 1/2 3, E 1/2 & SW4, 5, S 1/2 & NE6, W 1/2 & SE8, E 1/2 & SW9, E 1/2 & SW10, S 1/2 11, N 1/2 & SE13, N 1/2 & SE14, W 1/2 15, 16, SE17, 18, 19, 20, NW21, NE22, N 1/2 & SE23, 24, 25, 26, 27, 28, 29, E1/2 31, NW & SE32, S 1/2 33, S 1/2 34, S 1/2 & NE 35, S 1/2 & NE36
57	12	1, NE2, E 1/2 10, 11, 12, 13, 14, N 1/2 & SE15, E 1/2 21, 22, 23, W 1/2 & SE24, S 1/2 27

Twp.	Rge. W5M	Section
58	10	N 1/2 1, 2, 5, 6, 7, 8, W1/2 9, E 1/2 10, W 1/2 11, E 1/2 15, N 1/2 16, W1/2 & SE17, 18, 19, 20, 21, N 1/2 & SW 22, NW 23, NE 24, NW 26, W1/2 & SE27, 28, 29, 30, S 1/2 31, 32, 33, N 1/2 & SE34, SE35
58	11	1, E 1/2 2, E 1/2 11, 12, 13, 24, E 1/2 25, S 1/2 & NE36
59	10	SW2, N 1/2 & SE3, NW4, NE5, NW6
59	11	E 1/2 1

APPENDIX 2

FORESTS AND FLOODS

In order to establish a policy for timber management in the Paddle River headwaters (Map 2) it is essential to understand the interaction of forested land and climate on flood production. While these interactions are complex and vary in response from place to place, a number of consistent conclusions can be drawn from scientific research.

> *"In the regions where forests occur, total discharge, stormflow volume, and peak discharge are generally smaller than from adjacent nonforested land, but "smaller" is not a very significant qualification in the case of record peak flows and damaging floods. The forest influence becomes less important as the storm size, or flood size, increases; the chief mechanisms, interception and greater diversion to soil moisture storage, become relatively ineffective when these capacities are greatly exceeded by the volume of storm rainfall.*
>
> *The most important influence of forest cover on floods, and flood damages, has more to do with sedimentation and debris discharge than with the absolute volume or rate of flow. Organic and inorganic sediments obviously increase the flood volume, and when deposited in a stream channel will reduce its carrying capacity and increase the likelihood of overbank flooding; the sedimentation of reservoirs decreases their usefulness for flood control and other purposes. In general, 'dirty flood water is more damaging that relatively clean water, and sediment left by a flood*

can cause a substantial part of its total damage' (Anderson, Hoover, and Reinhart, 1976); it follows that 'as forest cover inhibits erosion, it significantly contributes to preventing flood damage.'

The forest provides the best possible cover for preventing flood damages, especially those that occur as the result of erosion and sedimentation; other land with complete vegetative cover may perform with comparable efficiency if undisturbed by human activity, fire, and overgrazing. Clearcutting, road-building, and other forest management activities, even surface mining, can be accomplished without increasing erosion or peak flows substantially, but too frequently the additional care and cost involved have discouraged the use of recommended procedures. Forest fire prevention, grazing restrictions, reforestation of abandoned land, and more strict control of clearcutting and other watershed disturbances are ways in which forest management can contribute to the reduction of flood damage" (Lee 1980).

Hewlett (1982) comments *"Returning to the specific question of forest influences on flood water discharge and flood stages, has recent experimentation and study of the question materially altered our conclusions? Harr (1979) summarizes experience with peak flows in a rather amusing way: 'Taken collectively results of watershed studies indicate that the size of peak flows may be increased, decreased, or remain unchanged after logging.' What better way to say that the variance of peak flow has been increased by logging but the mean change is negligible? Harr (1979) further concludes, 'If we cannot predict the consequences of harvesting activities on stormflow, then scheduling activities according to some formal procedure designed to maintain hydrologic balance will be largely an academic exercise and will be ineffective...' That's plain talk and it needs to be dealt with if we are to offer any practical advice to managers.*

I (Hewlett) *agree with Harr's statement but would like to raise the ante: The consequences of forest harvesting are sufficiently predictable from the evidence provided by the best conducted watershed experiments to say that forest harvesting, without subsequent cultivation or overgrazing of the basin, has negligible effects on flood levels in the valleys below the operations. In short, if we have so difficult a time measuring significant changes in stormflow volumes immediately below forest operations, what possible explanation can be used to account for more massive effects downstream?"* (Hewlett 1982).

Lull and Reinhart (1972), provide a thorough analysis of research findings regarding the relationship of forests and flooding in the eastern United States. This paper is still recognized as probably the best reference on the topic. Even though the climate and physical setting of the Eastern United States are different from Alberta, flood generation principles are the same.

1. *"The forest, because of its full occupancy, provides for any site a maximum opportunity for controlling runoff from flood-producing rainfalls; even so, the forest cannot prevent floods.*

2. *Interception, infiltration, and soil-moisture storage opportunity are the principal ways in which forest cover diminishes the discharge from flood-producing storms.*

3. *Infiltration capacities of the forest floor are almost everywhere greater than rainfall intensities. The Horton theory of excess rainfall as the source of overland flow and flood runoff does not apply in the eastern forest.*

4. *Forests, by preventing erosion and sedimentation, help to maintain stream-channel capacity so that they can carry storm flows with a minimum of flooding.*

5. *The principal source of flood runoff delivered to the channels in forested watersheds is subsurface flow that moves rapidly downslope through the permeable forest floor and topsoil.*

6. *Record flood discharges from forested mountain watersheds result from precipitation, soil, topography, and geology rather than the condition of their cover.*

7. *Changing rates of snow-melt by manipulating forest cover may either increase or decrease snow-melt peaks, depending on watershed conditions, including land-use diversification, and weather sequences.*

8. *Frost, concrete or otherwise, does not play an important role in the generation of flood peaks from forests.* (Note - the effects in Alberta may differ from the milder Eastern United States).

9. *Clearcut or burned, forest land in the East remains bare for but a brief period before rapid growth reclothes the site with sprouts, tree seedlings, and herbaceous plants.*

10. *The forest's influence on storm-flows is strongly modified by the size of the flow-producing storm, the area of the watershed as it affects channel storage capacity, and the season of storm occurrence.*

Second, about erosion-sedimentation:

1. *Erosion from the undisturbed forest occurs almost entirely within the stream channel as discharge detaches soil particles and carries them downstream; the upland forest, between the channels, contributes little or no sediment to the stream.*

2. *Erosion is not caused by cutting of trees, per se, but by the soil disturbance that usually accompanies or follows cutting.*

3. *Other things being equal, the greater the proportion of cropland in a watershed, the greater the sediment yield.*

4. *When pasture-grazing is not too heavy, the residual vegetation protects the soil well against erosion."*

The authors make the following inferences:

1. *"Clearcutting without serious disturbance of the forest floor does not drastically reduce infiltration rates and does not result in overland flow. It does result in reduced soil-moisture storage opportunity at some times; provided only a small proportion of the watershed is clearcut at any one time, increases in peak flow and flood runoff will not be large enough to be important.*

2. *With care, a forested watershed can be clearcut and the products can be removed without seriously lowering water quality.*

3. *Forest stands that have not been severely burned or grazed are performing their hydrologic function; there appears to be little opportunity for flood reduction through management methods, except by limiting the extent of heavy cutting.*

4. *The potential for reducing flood damages through forestry is greatest where forests can be established on nonforest lands that produce substantial amounts of overland flow."*

In summary:

> *"From our review of the influence of the Eastern forest on floods, we draw the following general conclusions:*
>
> - *The forest is the best of all possible natural cover for minimizing overland flow, runoff, and erosion.*
> - *With reasonable care, the forest can be cut with little detriment to its site-protective capability.*
> - *Under sustained-yield programs of forest management and with the great diversity in age classes... the extent of forest cutting offers no flood threat.*
> - *The flood-reduction role of the forest can be realized through continued fire protection and careful logging, and can be enhanced by reforestation of abandoned land* "(Lull and Reinhart 1972).

There is clearly a difference between the hydrologic impact of temporary forest removal and permanent land clearing for other uses.

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